Underemployment Index and Real Wage: the UK Perspective

Adam Gajtkowski

Supervised by Professor David Harvey

This Dissertation is presented in part fulfilment of the requirement for the completion of an undergraduate degree in the School of Economics, University of Nottingham. The work is the sole responsibility of the candidate.

Word count: 7495 May 7, 2018

Acknowledgments

I first would like to express the gratitude to my supervisor, Professor David Harvey, who guided me through this process. I also would like to express my gratitude to my parents and grandparents for constant support, staff at the University of Nottingham for helpful advice and rigorous preparation, and the Office for National statistics for supplying their data.

Table of Contents

Abstract 1

Chapter 1: Introduction 2

Chapter 2: Literature Review 4

- **2.1 Underemployment Literature** 4
- **2.2 Underemployment Rate** 7
- **2.3 Underemployment Index** 8

Chapter 3: Underemployment Index Methodology 10

- **3.1 Bell and Blanchflower Methodology** 10
- **3.2 Unemployment Rate Expressed in Hours** 11
- **3.3 Adding Overemployed and Underemployed Hours** 12
- **3.4 Limitations of Underemployment Index** 13
- **3.5 Updated Underemployment Index** 14

Chapter 4: Time Series Analysis 19

- **4.1 Data** 19
  - **4.1.1 Real Wage** 19
- **4.2 Stationarity** 20
  - **4.2.1 Pre-test Analysis and Augmented Dickey Fuller Tests** 20
  - **4.2.2 Real Wage Stationarity** 23
  - **4.2.3 Underemployment Index and Unemployment Rate Stationarity** 25
- **4.3 Obtaining Residuals** 27
- **4.4 Exploratory Time Series Regressions** 29
- **4.5 VAR Models** 32
  - **4.5.1 VAR Model of Real Wage and Underemployment Index** 34
  - **4.5.2 VAR Model of Real Wage and Unemployment Rate** 36
- **4.6 Granger Causality Tests** 37

Chapter 5: Summary 40

Bibliography 42

Appendices 45

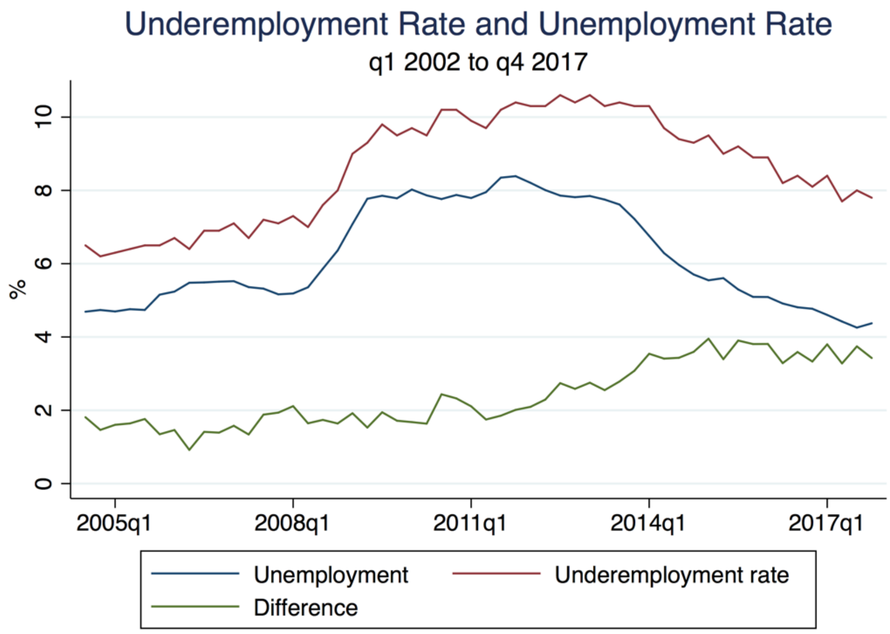
Abstract

I analysed short-term relationship between Bell and Blanchflower underemployment index growth and real wage growth. Current research suggests possible relationship between underemployment index and real wage, but researchers do not conduct econometric analysis of such relationship. This dissertation built on existing literature by updating underemployment index and analysing short-term relationship of real wage growth and underemployment index growth. To analyse the relationship, I firstly reconstructed underemployment index, adjusting Bell and Blanchflower methodology to ONS standards. I used quarterly data from the LFS, which cover period between 2000 q2 to 2017 q4. The results found, that in recent period underemployment index converges to unemployment rate, as both aggregated underemployed and overemployed hours are on similar levels. To test the relationship, I ran exploratory time series regression of real wage growth on lagged underemployment index growth, comparing results with regressions of real wage growth on lagged unemployment rate growth. I found real wage growth to be two times more responsive to changes in lagged underemployment index growth, than to changes in lagged unemployment rate growth. Next, I set two VAR models including real wage growth, underemployment index growth, and real wage growth, unemployment rate growth. I ran post estimation statistic, the Granger Causality tests. Results did not find any Granger-causation between underemployment index growth and real wage growth in any direction. There is also no Granger-causation between unemployment rate growth and real wage growth in any direction.

Chapter 1: Introduction

Underemployment in the UK is highly relevant and increasingly important issue, as the number of underemployed continue to rise relatively to unemployed workers (Graph 1). Historically changes in underemployment rate has been following changes in unemployment rate (2002-2010 period). However, since 2010 underemployment rate has begun to diverge from unemployment rate[1].

Graph 1 Underemployment Rate and Unemployment Rate. 2002 q1 to 2017 q4. Source: ONS



While unemployment has reached its lowest level since 1975 of 4.2% (in April 2018), time-related underemployment rate remains high at 7.8%[2]. Furthermore, Gregg and Fernandez-Salgado (2014) notice that the recent pattern in real wages represents the distinct break of a pre-downturn trend. One of the factors, which might explain stagnant wage growth on the British labour market is high number of underemployed people (Bell and Blanchflower, 2014).

[1] Graph 1 - green line shows the difference between underemployment rate and unemployment rate
[2] LFS data December 2017, ONS methodology

I may hypothesise, that underemployment index[3] could have become more accurate measure of the labour market slack than unemployment rate. In this context, it is reasonable to ask following questions:

1) What is the relationship between underemployment index growth and real wage growth in the UK?
2) Is underemployment index growth better predictor of real wage growth than unemployment rate growth?

To answer these questions, I structure my dissertation as follows: In the second chapter, I review underemployment literature and closely related empirical literature covering relationship between unemployment rate and wages. I review papers about underemployment index, focusing in particular on underemployment index construction. In the third chapter, I reconstruct underemployment index using ONS data and ONS standards of methodology. I analyse recent changes in underemployment index and relate them to previous findings of Bell and Blanchflower (2014). Chapter 4 focuses on the time-series analysis of real wage – underemployment index/unemployment rate relationships. I test these relationships using time-series regressions and the Granger causality tests. Chapter 5 summarises findings and concludes this dissertation.

The topic of underemployment – real wage dynamics is important from the perspective of governments, as it supplies more information about consequences of high underemployment. The established relation can help with decision-making process about active labour market policies, possibly extending them to those who are underemployed. Establishing the relationship can also benefit citizens, as it gives more insight about wage setting behaviour of employers (how employers react to changes in underemployment). In addition, underemployment has attracted some media attention recently (Business Insider UK[4], the Guardian[5]), however these articles can be misleading, as they report simply numbers of underemployed people in the UK. In my dissertation, I clarify the concept of underemployment and I elaborate on different measures of underemployment, discussing its limitations. This may help reader to understand the problem of underemployment in the UK.

---

[3] Bell and Blanchflower underemployment index (Bell and Blanchflower, 2013)
[4] http://uk.businessinsider.com/ons-underemployment-double-unemployment-rate-2017-9
[5] https://www.theguardian.com/business/2016/feb/29/millions-of-uk-workers-stuck-in-wrong-job-analysis-shows

Chapter 2: Literature Review

2.1 Underemployment Literature

Underemployment literature focuses analysis of trends concerning time-related underemployment in the UK (Bell and Blanchflower, 2013), psychological aspects of different types of underemployment and its consequences on lifetime earnings (Mc-Kee, 2011). Feldman (1996) distinguishes 19 types of underemployment. I focus on the time-related underemployment, which occurs when employees want to work more hours then they are currently working. Following Mc-Kee recommendation concerning future research, I rigorously define what exactly time-related underemployment is, firstly explaining ONS underemployment rate, and later explaining Bell and Blanchflower (2013) underemployment index.

Although there are no papers covering relationship between underemployment rate/index and real/nominal wages, there are many papers focusing on empirical relationships between wage and unemployment. Phillips (1958) suggests, that high unemployment restrain nominal wage changes. Also, Sargan (1964) suggests the level of wages depends on the level of unemployment. NAIRU proposed by Layard (1991) states that there exist a level of unemployment holding steady inflation and wage growth. Gali (2011) revisits the Phillips Curve implying that it may re-remerge in the US, while Hines, Hoynes and Krueger (2001) states that relationship between unemployment level and real wages fits data better than nominal wages used by Phillips. Examples of models used by above mentioned researchers are included in Table 1 below.

I base my analysis on recent paper published by Gregg and Fernandez-Salgado in 2014, analysing wage – unemployment sensitivities in the UK (equations in *Table 1,* motivation for these equations page 28, 30). I choose this paper, as it analyses period for the UK when data for constructing underemployment index is available, so that I can directly compare my results to the results of this paper. Gregg and Fernandez-Salgado analyse period between 1979 and 2012. Firstly, they show that recent patterns in wages has been broken in the early 2000s.

Average real wage growth between 1979 – 2003 was 0.65% for the 50th percentile of the wage distribution, while between 2003-2012 it became negative averaging at -1.39% for the same percentile. Next, Gregg and Fernandez-Salgado prove, that the unemployment has gained stronger influence on real wage growth, and discuss possible reasons behind changes in trend. Paper shows, that after year 2003 the wage dampening unemployment effect has become greater. Authors argue, that from the macroeconomic time series estimates wages are sensitive to unemployment levels, and that ”in the period of slowdown in real wage growth they became even more sensitive” (Gregg and Fernandez-Salgado, 2014).

Table 1 Selected Papers Covering Relationship between Unemployment Rate and Wage, or Real Wage

Paper Title	***Established Model***	***Explanation of Variables***	***Established Relationship***	***Time Period Covered (and country)***
Gregg and Fernandez-Salgado (2014)	(a) $\ln(W_t) = \alpha_1 + \delta_1 ln(U_{t-1}) + \lambda_1 t + \eta_t$ (b) $\ln(W_t) = \alpha_2 + \beta_2 \Delta ln(U_t) + \delta_2 ln(U_{t-1}) + \lambda_2 t + \upsilon_t$	$W_t - real\ wage$ U_{t-1} - *unemployment rate lagged one period* *t – time trend* U_t - *unemployment rate*	*The current period changes are badly determined by model (b).* *Negative correlation between ln wage and unemployment rate lagged one period model (a).*	*1979-2012 (UK)*
Phillips (1958)	*Phillips Curve* *log(y + a) = log b + c log(x)*	*y – rate of change of wage rates* *x – percentage unemployment* *constant b and c are*	*log(y + 0.900) = 0.984 + 1.394 log(x)* *High unemployment restrain nominal wage.*	*1861 – 1957 (UK)*

		estimated using OLS		
Gali (2011)	*New Keynesian Wage Phillips Curve* $\pi_t^w = \beta E_t\{\pi_{t+1}^{\omega}\} - \lambda_{\omega}\varphi(u_t - u^n)$	u_t*- rate of unemployment* u^n*- natural rate of unemployment* π_t^w*- wage inflation in period t* E_t*- an expectation operator*	*Wage equation may explain the strong negative relation between inflation of wages and unemployment (when looked at the past two decades).* *No Granger Causality at the 7 percent significance level.*	*Q1 1964 – Q3 2009 (US)*
Hines, Hoynes, Krueger. (2001)	$\Delta ECI = \alpha + \beta\Delta U_t + \gamma Y + \varepsilon_t$	*ECI – Real Total Compensation in the private sector (CPI)* U_t*- year to year change in level of unemployment* *Y – time trend*	*Changes in unemployment are uncorrelated with changes in real total compensation.*	*1980 – 1999(US)*

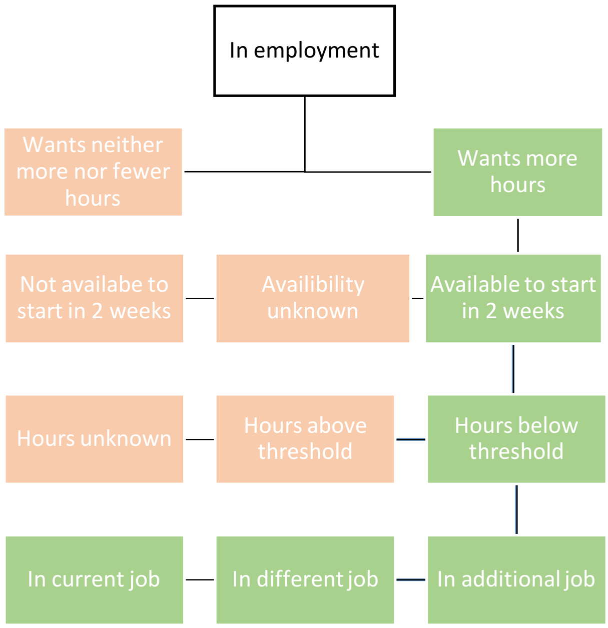
Bell and Blanchflower publish series of papers (2010 – 2014) concerning underemployment in the UK. Authors analyse situation on the British labour market and focus on number of people who are employed, unemployed and underemployed. In 2010 paper, authors notice that there has been significant underemployment after recession, which partially explains sluggish increase in unemployment. Authors highlight, that it is possible that underemployment and unemployment do not always change proportionally. Bell and Blanchflower (2011) analyse impact of the 2008 downturn on labour market and state that recession led to increase in temporary-contracts employment and reduction in full time employment in the UK. This phenomenon is not fully captured by the ONS unemployment rate. In a flexible labour market, an "adverse demand shock is likely to result in more workers wanting to work longer hours, fever wanting to reduce their working hours, and an expansion in temporary contracts" (Bell and Blanchflower, 2014). British labour market is considered to be flexible, that is why unemployment rate might not be the best measure of post-recession slack on the labour market.

In their 2013 paper, authors propose Bell and Blanchflower underemployment index as an alternative to unemployment rate (detailed methodology is described in subsections 2.3 and 3.1). Authors find, that the gap between underemployment index and unemployment rate has reached its highest level in 2013. Bell and Blanchflower states, that average worked hours did not fall between 2008-2012. Underemployment increases, while real wage falls sharply (between years 2008 - 2013). Authors do not conduct any econometric analysis concerning relationship between underemployment index and real wage. I build on Bell and Blanchflower (2013) findings and extend their research paper by conducting time-series analysis of this short-term relationship. In their final paper (2014) authors update labour market statistics and find that number of desired hours increased significantly through 2014, causing further increase in underemployment index. I also update Bell and Blanchflower underemployment index and describe changes in trends of the index (chapter 3). Before I do that, I review available underemployment measures.

2.2 Underemployment Rate

The Office for National Statistics classify underemployed people as those, who are willing to work more hours, are available to do so, and worked less than the specified hours of work threshold (Ons.gov.uk, 2018). ONS underemployment rate is the ratio of number those who are underemployed to all people in employment as shown in Figure 1 (Ons.gov.uk, 2018). This measure is expressed as a percentage. It is statistics, which does not reflect the aggregate level of underemployment. It sums number of people who want to work more. For instance, both those who want to work 10 more hours, and 20 more hours are count as unemployed. They are given equal weight in underemployment rate, although excess capacity of second a worker is twice as much as the first worker. Another drawback of underemployment rate is that it does not include those who are overemployed (want to work less hours, but are unable to do so - e.g. lawyers). Underemployment rate and unemployment rate cannot capture phenomenon of underemployment and overemployment, although data to include those variables is available for the UK in the Labour Force Survey.

Figure 1 Underemployment Rate: the ONS Methodology. Source: ONS



I compare aggregate influence of changes in the slack of the labour market growth on real wage growth. To do that, I use index proposed by Bell and Blanchflower (2013) instead of ONS underemployment rate, because Bell and Blanchflower (2013) include those, who are unemployed, underemployed, and overemployed. Researchers express underemployment index not as a ratio of number of people within particular groups (e.g. unemployment rate, underemployment index), but they express it as a ratio of hours (equation 2).

2.3 Underemployment Index

Bell and Blanchflower (2013) propose to measure slack on the labour market in a more accurate manner, by modifying unemployment rate (u). Bell and Blanchflower underemployment index is expressed as a ratio of unutilised hours to all hours available within given economy. It includes both intensive (hours) and extensive (jobs) margins of the labour market.

Firstly, general formula for unemployment has been transformed by multiplication number unemployed (U) and employed (E) by averaged worked hours $\bar{h}$ - equation (1). Bell and

Blanchflower (2013) assume, that those who do not express a wish to work more/less hours are content. Another assumption is that unemployed would want to work on average the same amount of hours (averaged hours worked) as employed. Researchers estimated weekly hours regression based on those employed and used estimates to predict hours for the unemployed. There was no significant difference between predictions and average hours worked, so it is simpler to worked with average hours of employed as predictor.

(1) $$u = \frac{U}{U+E} = \frac{U\bar{h}}{U\bar{h}+E\bar{h}} = \frac{U\bar{h}}{U\bar{h}+\sum_i hi}$$

Multiplying number of employed people by average hours worked ($E.\bar{h}$) by definition is equivalent to summation of all hours utilised within an economy denoted as $\sum_i h_i$.

Next, Bell and Blanchflower include overemployed and underemployed hours within unutilised hours (in nominator). Authors add number of additionally desired hours ($\sum_k \widetilde{h_k^u}$) and subtract sum of hours employees want to reduce ($\sum_j \tilde{h}_j^o$). These modifications yield Bell and Blanchflower underemployment index u_{bb} – equation (2). See Table 2 for description of variables and data sources.

(2) $$u_{bb} = \frac{U\bar{h}+\sum_k \widetilde{h_k^u} - \sum_j \tilde{h}_j^o}{U\bar{h}+\sum_i h_i}$$

One of the limitations, which arises during comparison of underemployment index to unemployment rate, is that unemployment rate is based on objective data, while data included within underemployment index are partially subjective. Estimates about working hours' preferences are based on survey data and imputed by individuals (*Table 3 – survey questions*). I need to assume that these answers reflect reality, as it is the best approximation and best estimate of workers' preferences. It might not be true as for instance person filling in survey might think that they can work more hours, but in reality they would not be able to. It might be also the case that some survey takers simply do not tell the truth.

Chapter 3: Underemployment Index Methodology

In this chapter, I compute underemployment index and comment on changes in its trend. Bell and Blanchflower (2013) estimated underemployment index for the UK using individual data provided in the Labour Force Survey (LFS), accessed on the UK Dataservice website[6]. Quarterly survey also provides necessary data for estimation of the ONS unemployment rate and underemployment rate. Each LFS includes approximetaly 130,000 observations representative for the whole UK.

3.1 Bell and Blanchflower Methodology

Bell and Blanchflower use LFS to calculate unemployment rate using weights provided by the ONS. Authors include those who are employed, self-employed, family workers and those on government schemes to calculate total employment and average working hours. Researchers used X-13ARIMA-SEATS method of seasonal adjustment. They show that seasonal adjustment does not make any significant difference in estimate of underemployment index. In other words, authors report "quarterly seasonal effects to be small" (Bell and Blanchflower, 2013). Bell and Blanchflower follow ONS definition of underemployment and overemployment. For underemployment, authors do not take into consideration those aged 16-19 working 40 or more hours, and those aged over 18 working 48 hours or more. For underemployment, subjects aged 16 – 18 working 15 hours or less are not considered. Subjects aged 18 and more working 20 hours and less are not taken into consideration as well (Bell and Blanchflower, 2013).

[6] https://www.ukdataservice.ac.uk

3.2 Unemployment Rate Expressed in Hours

I use ONS estimates of average weekly hours worked, number of people in employment and number of unemployed people. All data are seasonally adjusted by the ONS. I use ONS data as I want to directly compare ONS unemployment rate with Bell and Blanchflower underemployment index. Changes in methodology, or different method of seasonal adjustment (as proposed by Bell and Blanchflower) could distort direct comparison. I perform quality assurance, by comparing ONS unemployment rate with unemployment rate expressed as a ratio of hours I computed. Both rates are identical. There are four exceptions associated with approximation rules, as the ONS round numbers such as 5.05 down to 5.0, while it should be round up to 5.1. It does not significantly affect underemployment index calculated by me.

Table 2 Underemployment Index Variables – Using ONS Methodology

Notation	Name of Variable	Source
u	Unemployment rate	-
u_{bb}	Underemployment index	-
E	Number of employed people	ONS: Number of people in employment
U	Number of unemployed people	ONS: number of unemployed people
$\bar{h}$	Average number of hours worked	ONS: Average actual hours worked by all workers
$\sum_i h_i$	Sum of total hours worked within economy	ONS Total hours worked
$\sum_k \widetilde{h_k^u}$	Sum of additionally desired hours	Underemployment in the UK:ONS (sum not seasonally adjusted)
$\sum_j \tilde{h}_j^o$	Sum of hours employees want to reduce	Overemployment in the UK:ONS (sum not seasonally adjusted)

3.3 Adding Overemployed and Underemployed Hours

In order to calculate underemployment index, I estimate sum of underemployed and overemployed hours and transform it from sample data to population estimates. I do not use seasonal adjustment, as I have already included 3 variables; unemployed, employed, average hours worked, which are seasonally adjusted by the ONS. Bell and Blanchfower (2013) note that seasonal adjustment does not change estimates significantly. To calculate sum of underemployed/overemployed hours I consider data based on following questions in the Labour Force Survey (Ons.gov.uk, 2018):

Table 3 Selected Questions from the Labour Force Survey

252 UNDEMP

Would you prefer to work longer hours at your current basic rates – that is, not overtime or enhanced pay rates – if you were given the opportunity?

1	yes
2	no

Applies if respondent is not looking for a different or additional job.

253 UNDHRS

How many extra hours, in addition to those you usually work, would you like to work each week?

97 = 97 or more

99 = do not know or refusal

Applies if respondent would prefer to work longer hours.

262

Would you prefer to work shorter hours than at present in your current job?

1	yes
2	no

Applies DIFFJOB=2 (not looking for another job)

and UNDEMP=2 (does not want job with more hours)

264 OVHRS

How many fever hours would you like to work in that/your current job?
97 = 97 or more
99 = don’t know or refusal
applies if LESPAY=1 (work shorter hours for less pay)
or if LESPAY3 = 1 (work shorter hours in current job for less pay)

I compute underemployed/overemployed hours for each quarter using the LFS. For underemployed hours, firstly I detect all underemployed people. Then, I multiply amount of additionally desired hours given underemployed individual reports by weight assigned to this observation (by the ONS). In the end, I sum all additionally desired hours within whole sample at a given quarter. I repeat symmetric procedure for all overemployed people in each quarter. Those estimate return number of underemployed hours and overemployed hours for each quarter from 2000 q2 to 2017 q4.

Weight assigned to each observation within LFS is a numerical value used to transform sample data to data representative for whole population. I use historical weights (PWT07 to PWT 16) for years 2000 to 2016 to transform sample estimates into population estimates. I use weights PWT17 for data starting in q3 2016, as they are included in the LFS (*Table 4*) available for researchers.

3.4 Limitations of Underemployment Index

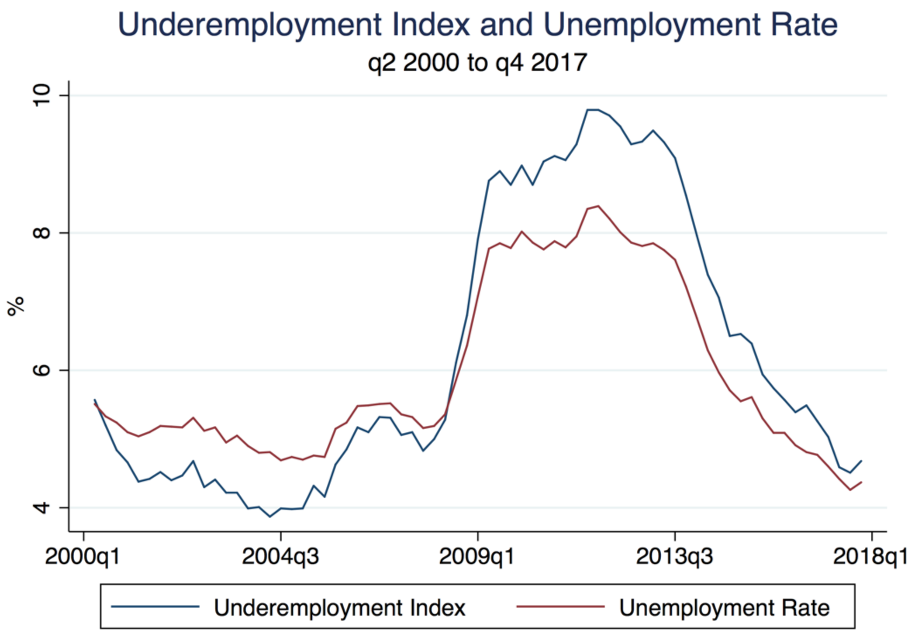
Although underemployment index appears to be more accurate measure of slack on the labour market than unemployment rate and underemployment rate, it has several shortcomings. The first drawback, concerning reliability of data reported by individuals, is highlighted in section 2.3. Next, it may happen that overemployed hours are equal to underemployed hours. In that case underemployment index is the same as unemployment rate as shown in equation 3 (Bell and Blanchflower, 2014).

(3) If $\sum_k \widetilde{h_k^u} = \sum_j \tilde{h}_j^o$, then $u = u_{bb}$

This suggests that underemployment index might show less slack on the labour market than in reality. I assume that underemployment hours cannot be freely traded to hours of those who are overemployed, as there exists transaction costs and skill miss-match. In that case it would be reasonable to introduce an additional penalty term. Although I focus is on the underemployment index analysis, I briefly analyse mismatch on labour market which can be simply express as a sum of underemployed and overemployed hours. The smaller is sum, the smaller is mismatch.

3.5 Updated Underemployment Index

Graph 2 Underemployment Index and Unemployment Rate. q2 2000 to q4 2017. Source: LFS



Both underemployment index and unemployment rate continue to fall in years 2014 – 2017 (Graph 2). They reach its pre-downturn level in 2017 q1 and later drop to even lower levels. In 2017 q4 the difference between underemployment index and unemployment rate is just 0.31 percent point. Initially, it suggests that the British labour market comes back to its pre-downturn equilibrium in terms of its overall level, as well as underemploymed/overemployed hours. However, when I look at the Graph 3, which shows the sum of underemployed and overemployed hours, it is visible that underemployment index and unemployment rate are similar, because underemployed hours and overemployed hours cancel each other out. Aggregate level of unutilised hours and not desired additional hours is actually historically high. The overall sum of mismatched hours increased in 2007 q3 and remained at the same high level. Underemployed hours remain at the high post-downturn level, while desired reductions increased since 2013 q3. This situation highlights, that researchers need to be aware of limitations of the Bell and Blanchflower underemployment index, because it does not necessarily capture total excess capacity on a labour market. Bell and Blanchflower (2014) argued that the index gives a broader estimate of the extent of unused capacity within economy. This could be true for the post-downturn period they analysed, when underemployed hours greatly exceeded overemployed hours. However, I would always suggest reporting underemployed/overemployed hours next to underemployment index, to give more insight into the condition of a labour market.

Graph 3 Sum of Underemployed (red) and Overemployed (blue) Hours (Millions). UK, q2 2000 to q4 2017. Source: LFS

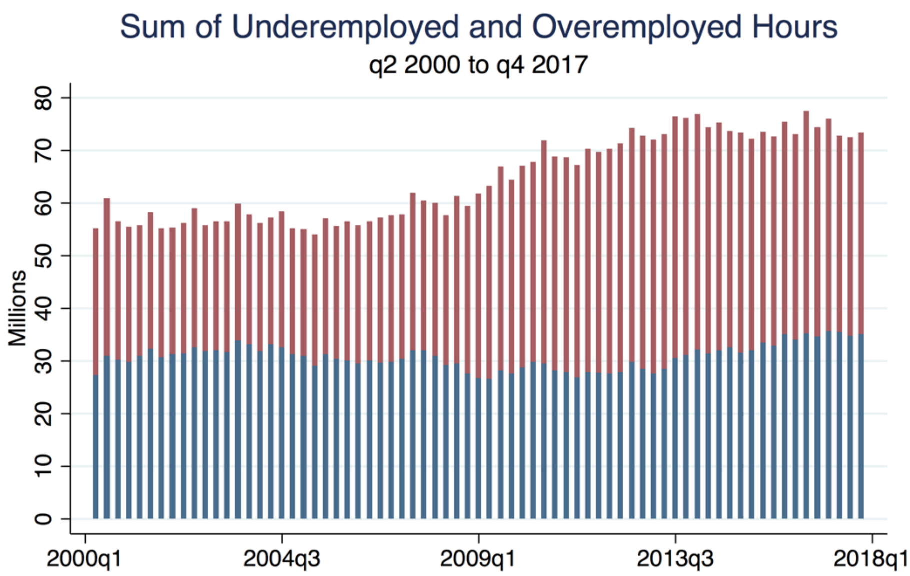


*Table 4 Underemployment Index, Unemployment Rate, Weights. q2 2000 to q2 2017. Estimates Using the Labour Force Survey (ONS)**

Year	Quarter	Underemployment index	Unemployment rate (hours ratio)	Weights (ONS)
2000	q2	5.57	5.51	PWT07
	q3	5.20	5.33	PWT07
	q4	4.84	5.24	PWT07
2001	q1	4.66	5.10	PWT07
	q2	4.38	5.04	PWT07
	q3	4.42	5.10	PWT10
	q4	4.52	5.19	PWT10
2002	q1	4.40	5.18	PWT10
	q2	4.47	5.17	PWT10
	q3	4.68	5.31	PWT10
	q4	4.30	5.12	PWT10
2003	q1	4.41	5.17	PWT10
	q2	4.22	4.95	PWT10
	q3	4.22	5.05	PWT10
	q4	3.99	4.90	PWT10
2004	q1	4.01	4.80	PWT10
	q2	3.87	4.81	PWT10
	q3	3.99	4.69	PWT10
	q4	3.98	4.74	PWT10
2005	q1	3.99	4.70	PWT10
	q2	4.32	4.76	PWT10
	q3	4.16	4.74	PWT10
	q4	4.63	5.15	PWT10
2006	q1	4.85	5.24	PWT10
	q2	5.17	5.48	PWT10
	q3	5.10	5.49	PWT10
	q4	5.32	5.51	PWT10
2007	q1	5.31	5.52	PWT10
	q2	5.06	5.36	PWT10

	q3	5.10	5.32	PWT10
	q4	4.83	5.16	PWT10
2008	q1	5.00	5.19	PWT10
	q2	5.28	5.36	PWT10
	q3	6.11	5.86	PWT10
	q4	6.80	6.36	PWT10
2009	q1	7.91	7.08	PWT10
	q2	8.76	7.77	PWT10
	q3	8.90	7.85	PWT11
	q4	8.70	7.78	PWT11
2010	q1	8.98	8.02	PWT11
	q2	8.70	7.86	PWT11
	q3	9.04	7.76	PWT11
	q4	9.12	7.88	PWT11
2011	q1	9.06	7.79	PWT11
	q2	9.29	7.95	PWT11
	q3	9.79	8.35	PWT11
	q4	9.79	8.39	PWT11
2012	q1	9.71	8.21	PWT11
	q2	9.55	8.01	PWT11
	q3	9.29	7.86	PWT11
	q4	9.33	7.81	PWT11
2013	q1	9.49	7.85	PWT11
	q2	9.32	7.75	PWT11
	q3	9.09	7.61	PWT11
	q4	8.55	7.22	PWT11
2014	q1	7.96	6.76	PWT11
	q2	7.39	6.29	PWT11
	q3	7.06	5.97	PWT14
	q4	6.50	5.71	PWT14
2015	q1	6.53	5.55	PWT14
	q2	6.39	5.61	PWT14
	q3	5.94	5.30	PWT14

	q4	5.74	5.09	PWT14
2016	q1	5.57	5.09	PWT16
	q2	5.39	4.91	PWT16
	q3	5.49	4.81	PWT17
	q4	5.26	4.77	PWT17
2017	q1	5.03	4.60	PWT17
	q2	4.59	4.42	PWT17
	q3	4.51	4.26	PWT17
	q4	4.68	4.37	PWT17

**Hours not seasonally adjusted. Seasonal adjustment of unemployment rate performed by the ONS.*

Chapter 4: Time Series Analysis

The aim of this chapter is to test the short-run relationship between average real wage (total weekly pay deflated by Consumer Price Index) and underemployment index (Bell and Blanchflower, 2013), and discuss these findings. As I have computed underemployment index in previous chapter, I may now start empirical part. My empirical work consists of several stages. Firstly, I test for stationarity of all relevant variables. Next, I run exploratory time series regressions to test the relationship between underemployment index and real wage; unemployment rate and real wage. After that, I build VAR models and run the Granger Causality tests.

4.1 Data

To analyse the relationship, I use three variables: unemployment rate, underemployment index and real wage. I base model specification on Gregg and Fernandez-Salgado (2014) paper. Authors use yearly data in their publication. I use quarterly data, as underemployment index is only available between years 2000 and 2017. Using yearly data would result in 17 observations. According to Box and Tiao (1975) this is not sufficient amount of observations for time series analysis.

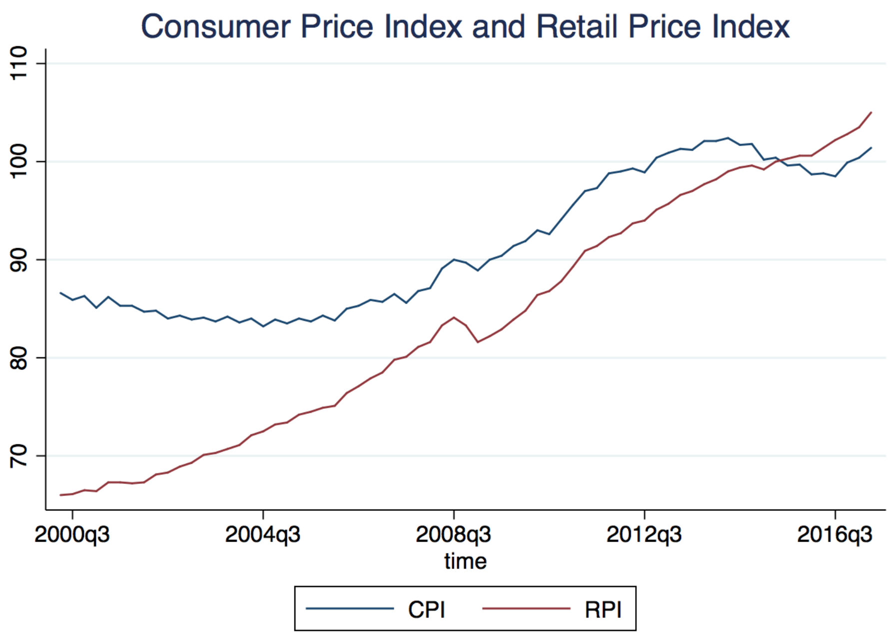
4.1.1 Real Wage

To calculate real wage, I use the ONS average weekly earnings (total pay – *Table 19* in appendices). To obtain quarterly data, I take three months' average. Gregg and Fernandez-Salgado (2014) use yearly New Earnings Survey (NES) and Annual Survey of Hours and Earnings (ASHE) data sets. These data are based on larger population sample, accounting for approximately 1% of all workers. Because these are yearly data, I need to use smaller sample ONS data.

In my work, I use CPI to deflate nominal wage (*Table 19*). Gregg and Fernandez-Salgado (2014) test robustness using different deflators. They include RPIJ and GDP deflators, which are no longer produced by the ONS. CPIH deflator, currently recommended by the ONS

(Ons.gov.uk, 2018), is available just from 2005. In my work I can use either CPI, or RPI deflator. I use CPI, as it meets international standards (contrary to RPI) and it is less volatile than RPI (Graph 4).

Graph 4 Consumer Price Index (CPI) and Retail Price Index (RPI), 2000 q2 to 2017 q4, Index 2015=100. Source: ONS



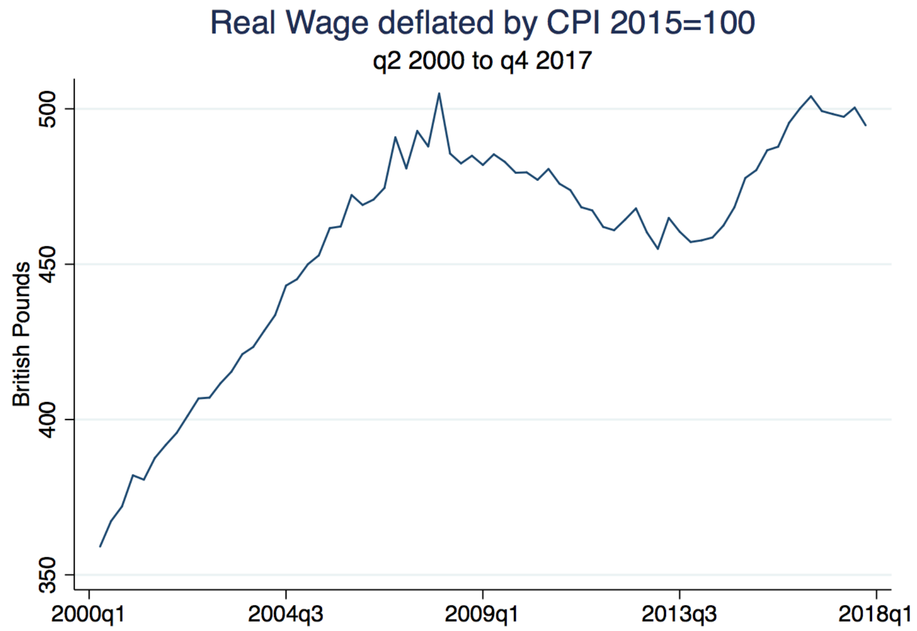
4.2 Stationarity

Time series analysis requires stationary variables. The main reason why I need to test for the presence of a unit root is the spurious regression discussed by Granger and Newbold (1974) and Phillips. In case of presence of a unit root in either real wage, unemployment rate, or underemployment index, even if those variables are independent, estimators and tests might suggest that there is a relationship between them (Hamilton, 1994).

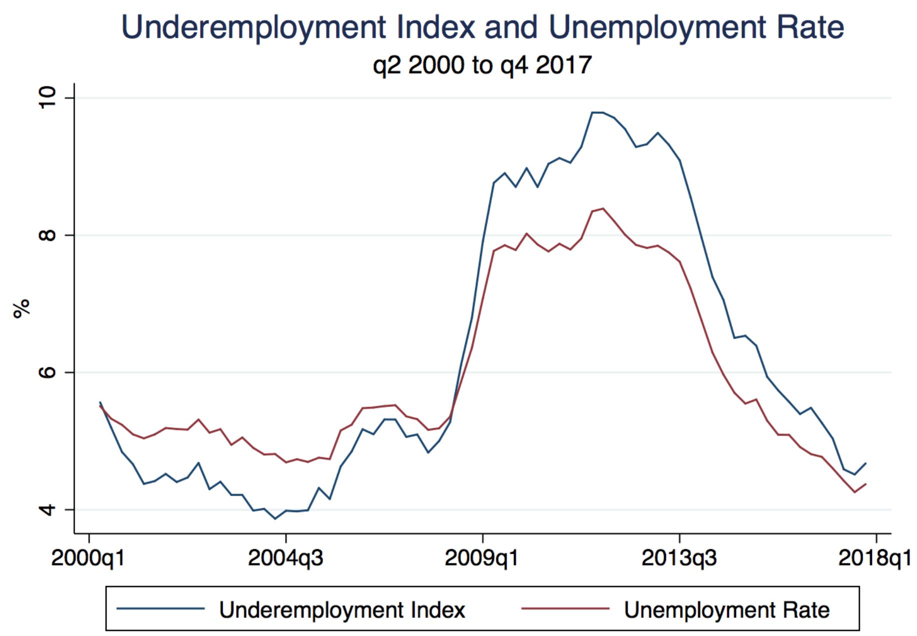
4.2.1 Pre-test analysis and Augmented Dickey Fuller Tests

Between q2 2000 and q3 2008 real wage resembles trend stationary model (Graph 5). Real wage growths over time with fluctuations around the trend (as in Keynesian theories). The effect of unexpected shock, the 2008 downturn, is persistent. Level of wages stagnates after this shock and does not come back to the pre-downturn trend. This may suggest that real wage follows a unit root model (such as in real business cycle models) – it has a long memory.

Graph 5 Real Wage (W). British Pound, q2 2000 to q4 2017, Deflated by CPI 100 = 2015. Source: ONS



Graph 6 Underemployment Index and Unemployment Rate. q2 2000 to q4 2017. Source: LFS



Now let us look at the Graph 2 from page 14 again, this time in context of stationarity (Graph 6). Unemployment rate and underemployment index follow a similar path over time. Within period I analyse, the 2008 downturn affects both variables similarly. It is possible, that in the longer period these variables are stationary, as the 2008 shock does not have a permanent impact on its level. Both unemployment rate and underemployment index come back to its pre-downturn level in 2017 q3.

Table 5 Summary Statistics

Variable	Number of observations	Mean	Standard Deviation	Minimum Value	Maximum Value
Underemployment index	71	6.22	2.01	3.87	9.79
Unemployment rate	71	5.94	1.28	4.26	8.39
Real Wage	71	457.34	37.19	359.13	504.92

According to Box and Tiao (1975) I should have at least 50, ideally more than 100 observations for time series analysis. Time series consists of 71 observations which is sufficient for analysis. Summary statistics of three times-series are reported in *Table 5*.

In order to test for stationarity, I initially run Augmented Dickey-Fuller unit root test and confirm findings with Phillips-Perron test. The advantage of Phillips-Perron test is that it controls for heteroskedasticity, which might be in error term in the augmented Dickey-Fuller test. Augmented Dickey-Fuller test has the null hypothesis that a variable contains a unit root. If null is rejected, I may assume that given time series is stationary (Hamilton, 1994).

Running Augmented Dickey-Fuller test requires specification of number of lags (p). If p is too small, Augmented Dickey-Fuller test might be biased. Too large p will result is loss of power of a test. I choose number of lags according to Schwarz Information Criteria. I also need to specify maximum number of lags before obtaining lag-order selection statistics. I set maximum lag number according to the formula suggested by Schwert (1989): $p_{\max} = \left[12\times\left(\frac{T}{100}\right)^{0.25}\right]$. It gives maximum number of lags approximately 11 in case of 71 observations. I round this number up, as Monte-Carlo Experiments suggests that it is better to error on the side of including too many lags (Faculty Washington, 2018). I keep default confidence interval of 0.95.

Augmented Dickey-Fuller tests finds that the real wage is integrated of order two, unemployment rate and underemployment index are integrated of order one (*Table 20* - *Table 26* in appendices). I confirm these findings with Phillips-Perron tests. It is rather unusual to find macroeconomic variables, which need to be integrated twice. Mosconi, Rocco, and Paruolo (2017) finds variables such as: models of stock and flow; inventories; consumption; income to be integrated of order two. I would expect real wage to be trend stationary, or integrated of order one.

Conventional unit root tests I used are biased toward a false unit root null, when the data are trend stationary with a structural break (Perron, 1989). I need to take into consideration existing trends and structural breaks in my data. If not, I may fail to reject the null hypothesis that the time series contains a unit root (Perron, 1989). Perron suggests to incorporate a breakpoint into the regression model and apply tests similar to the standard Dickey-Fuller unit root test.

4.2.2 Real Wage Stationarity

I set up real wage structural break stationarity test (Perron, 1989) based on following description. Between 2000 q2 and 2008 q3 real wage has trending behaviour (Graph 5). As a consequence of the 2008 downturn it shifts to a non-trending behaviour (there is trend break and level shift). The 2008 q3 downturn causes a structural break in wages (I know the break date) and break occurs immediately.

I specify model (4) of trending data with intercept and trend break. Firstly, I perform unit root test on raw data (Level). I choose lag number based on Bayesian Information Criteria, set maximum lag to 11 (Schwert, 1989). I choose break type to be additive outlier (based on graphical analysis), which is a one-off effect of a break (Patterson, 2000).

(4) $$y_t = \alpha + \beta t + \delta_1 DU_t(T_b) + \delta_2 DT_t(T_b) + \varepsilon_t$$

(5) $$DU_t(T_b) = 1(t \geq T_b)$$

(6) $DT_t(T_b) = 1(t \geq T_b)(t - T_b + 1)$

I assume there is a structural break in the third quarter of 2008 (when Lehman Brothers collapses – peak point of the 2008 downturn) and denote it by T_b. $DU_t(T_b)$ is an intercept variable which takes value one once structural break T_b occurs. $DT_t(T_b)$ is a trend break variable which occurs for t greater, or equal T_b (Perron, 1989). I apply monotonic (natural logarithm) transformation to the real wage.

Table 6 Unit Root Test with a Breakpoint: Log Real Wage

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-2.96	-4.88	-4.24	-3.96	0.10

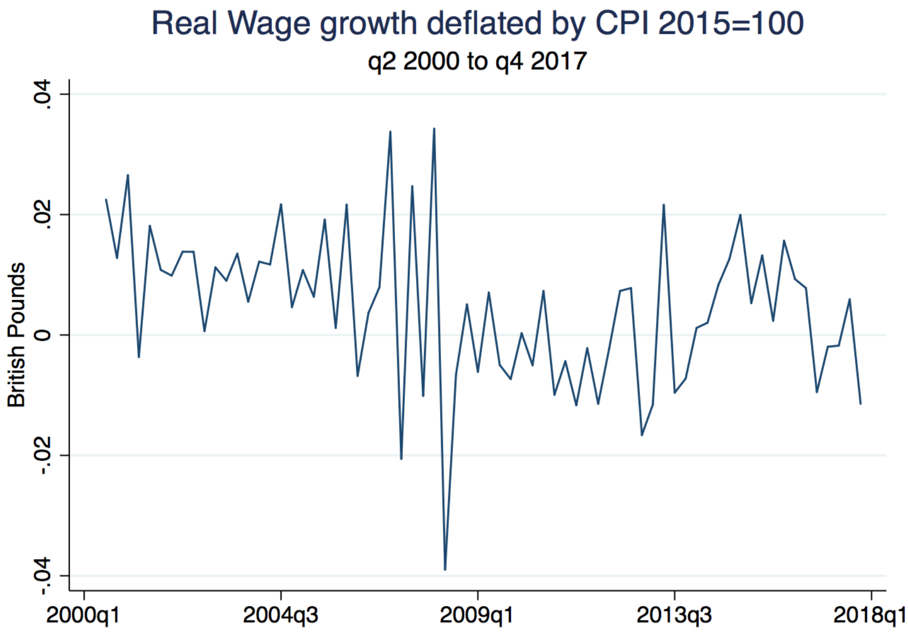
In my model, the null hypothesis is that time series contains a unit root with change in the level and slope. If I reject it, I assume that the series is trend stationary with changes in the intercept and the slope. I can not reject the null hypothesis, that the model contains a unit root, as the p value of 0.10 is greater than 0.05 level *(Table 6)*.

Table 7 Unit Root Test with a Breakpoint: Log Real Wage (First Difference)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-12.52	-4.87	-4.23	-3.95	.01

I take first difference of natural logarithm real wage. I assume again model (4) with trending data (the time series exhibits trend before 2008 q3 – Graph 7), constant and the intercept break $DU_t(T_b)$ – 2008 q3. I found real wage to be integrated of order one, with change in the intercept and the trend in 2008 q3. I reject the null hypothesis that the series contains a unit root, since the p-value is at a 1% level of significance (*Table 7*).

Graph 7 Real Wage Growth. British Pounds, q2 2000 to q4 2017, Deflated by CPI 100 = 2015



4.2.3 Unemployment Rate and Underemployment Index Stationarity

Standard Phillips-Perron unit root test and Augmented Dickey-Fuller test find unemployment rate and underemployment index to be integrated of order 1. Both time series appear to have structural break as a consequence of the economic crisis. After the 2008 downturn, the time series exhibit negative trend (Graph 6). I perform unit root test with a break point and change in trend as specified in equation (4) assuming structural break to occur in the third quarter of 2008. I express both time series in natural logarithm.

Table 8 Unit Root Test with a Breakpoint: Log Unemployment Rate

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-2.36	-4.88	-4.24	-3.96	.50

Table 9 Unit Root Test with a Breakpoint: Log Unemployment Rate (First Difference)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-4.86	-4.33	-3.75	-3.45	.01

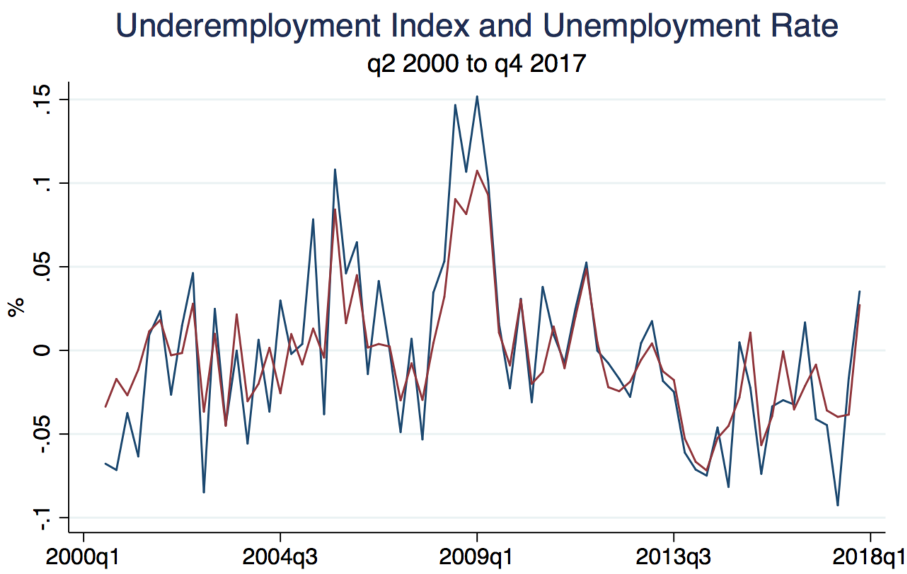
Table 10 Unit Root Test with a Breakpoint: Log Underemployment Index

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-2.02	-4.88	-4.24	-3.96	.50

Table 11 Unit Root Test with a Breakpoint: Log Underemployment Index (First Difference)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-3.91	-4.33	-3.75	-3.45	.05

Graph 8 Underemployment Index (blue) Growth and Unemployment Rate (red) Growth



I cannot reject null hypothesis that unemployment rate and underemployment index contain a unit root, as specified in model (4), as p-values are 0.50 (*Table 8* and *Table 10*).

(7) $y_t = \alpha + \delta_1 DU_t(T_b) + \varepsilon_t$

Next, I take first difference of log underemployment index and log unemployment rate. I assume a model (7) with non-trending data, constant, and an intercept break $DU_t(T_b)$ – 2008 q3 (see Graph 8). P-values of 0.01 and 0.05 for log unemployment rate growth and log underemployment index growth respectively (*Table 9* and *Table 11*) allow to reject the null hypothesis. I find both time series to be integrated of order one, with change in the intercept in the third quarter of 2008.

4.3 Obtaining Residuals

In order to perform analysis of the relationship between real wage growth and underemployment index/unemployment rate growth I need to obtain residuals of those variables, which account for changes in trends and intercepts. I base this approach on the Frisch-Waugh-Lovell theorem. Time series have either change in trend and intercept (real wage growth), or just intercept (unemployment rate growth and underemployment index growth) in the third quarter of 2008.

In order to obtain residuals of real wage ($\varepsilon_{w,t}$), I will regress first difference of log real wage on change in intercept $DU_t(T_b)$ and time trend $DT_t(T_b)$ – see equation (8).

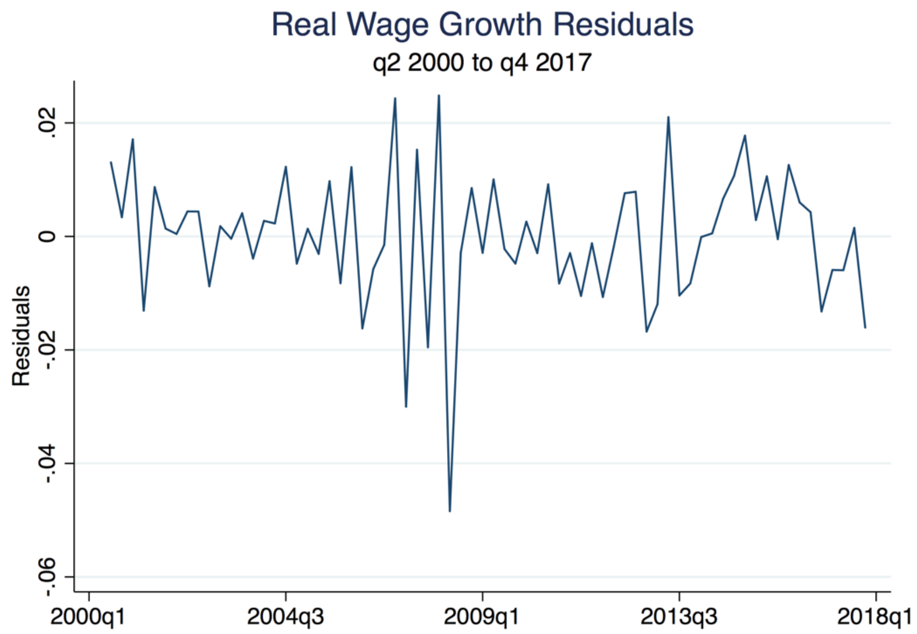
(8) $\Delta ln(w_t) = \alpha_1 + \delta_{11} DU_t(T_b) + \delta_{12} DT_t(T_b) + \varepsilon_{w,t}$

Both underemployment index and unemployment rate are integrated of order one once I exclude intercept break. In order to obtain residuals ($\varepsilon_{und,t}$ and $\varepsilon_{u,t}$) I regress underemployment index growth and unemployment rate growth on constant and intercept break $DU_t(T_b)$ – equations (9) and (10).

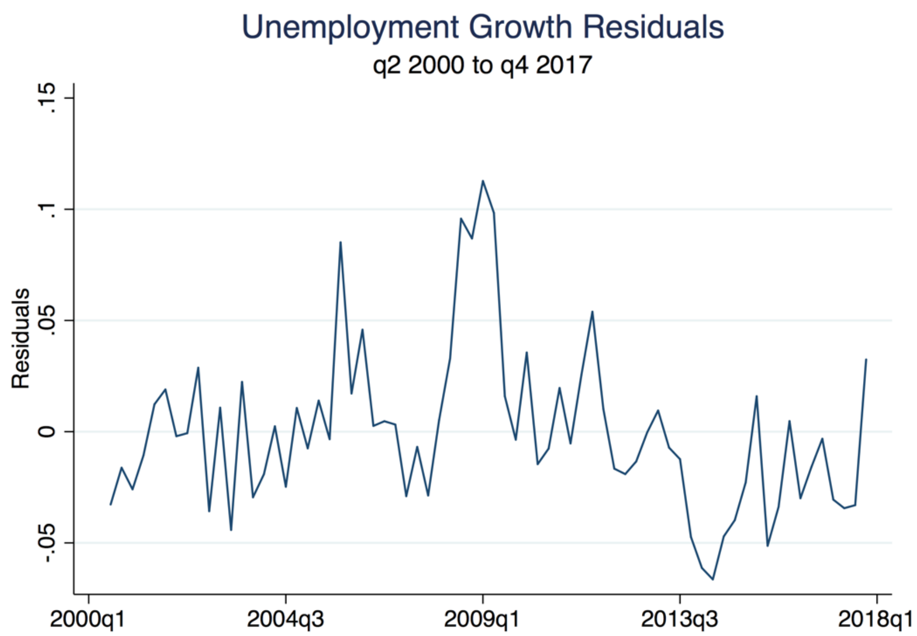
(9) $\Delta ln(u_t) = \alpha_2 + \delta_{21} DU_t(T_b) + \varepsilon_{u,t}$

(10) $\Delta ln(und_t) = \alpha_3 + \delta_{31} DU_t(T_b) + \varepsilon_{und,t}$

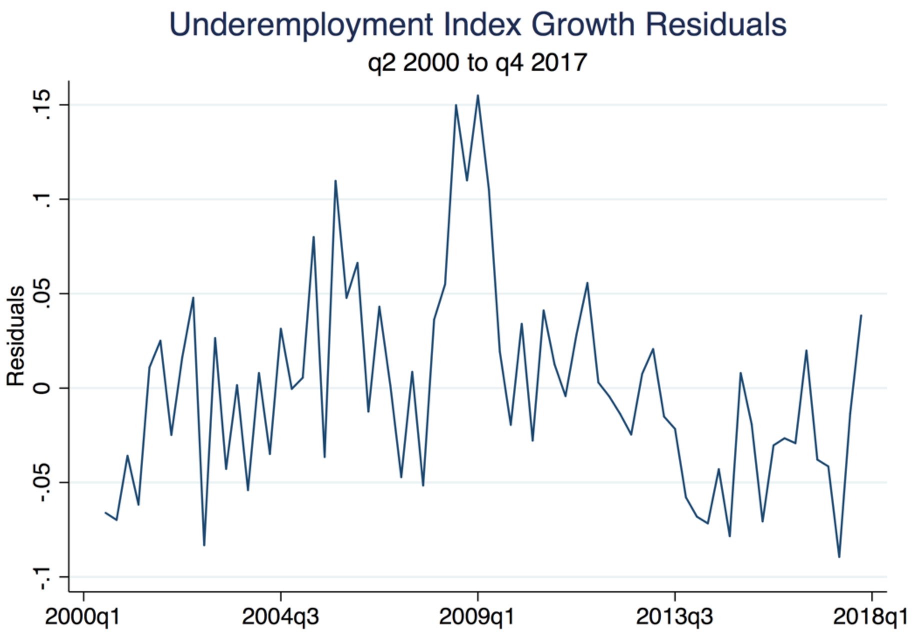
Graph 9 Real Wage Growth Residuals (First Difference of Natural Logarithm). q2 2000 to q4 2017, deflated by CPI 100 = 2015



Graph 10 Unemployment Rate Growth Residuals (First Difference of Natural Logarithm). q2 2000 to q4 2017



Graph 11 Underemployment Index Growth Residuals (First Difference of Natural Logarithm). q2 2000 to q4 2017. Source: ONS



4.4 Exploratory Time Series Regression

I follow methodology of analysing sensitivities published by Gregg and Fernandez-Salgado (2014). In particular, I focus on running two exploratory time series regressions at the economy-wide level.

(11) $\ln(W_t) = \alpha_1 + \delta_1 ln(U_{t-1}) + \lambda_1 t + \eta_t$

Equation (11) from their paper relates the log real wage in period t solely to the log unemployment rate in period (t - 1) and a trend. Unemployment rate is lagged one period "to reduce the potential for current prevailing economic conditions to be both driving unemployment and wage movements" (Gregg and Fernandez-Salgado, 2014).

I run regression based on above specification for both unemployment rate and underemployment index. I expect my results to be different to Gregg and Fernandez-Salgado, as I analyse quarterly data, shorter period, and work on first differences.

Natural logarithms of wages and underemployment index are not stationary within period I analyse. In order to analyse similar relationship to (11) I need to modify this model. I try to establish short-run relationship, where all data is stationary. I regress residuals of first difference of log real wage on residuals of first difference of lagged log underemployment index/unemployment rate – as defined in subsection 4.3. I suppress constant term and report robust standard errors (robust to heteroskedasticity – as I work with survey data).

(12) $\varepsilon_{w,t} = \delta_2 \varepsilon_{und,t-1} + \upsilon_{1t}$

(13) $\varepsilon_{w,t} = \delta_3 \varepsilon_{u,t-1} + \upsilon_{2t}$

Table 12 Exploratory Time Series Regression (12) and (13)

Regression of Real Wage Residuals on Underemployment Index/Unemployment Rate Residuals*	
Underemployment Index (t-1)	-.0308 (.0262)
Unemployment Rate (t-1)	-.0178 (.0298)

**Robust standard errors in parentheses.*

Table 12 shows correlations between real wage growth and lagged underemployment index/unemployment rate growths. Gregg and Fernandez-Salgado (2014) find that there is a significant wage restraining impact of lagged log unemployment on median log real wages (equation 11: δ_1 = -.184 for 2003-2012). I find that for period (q2 2000 to q4 2017) there is a negative relationship between lagged unemployment growth and real wage growth (-.0178). 1% increase in lagged unemployment growth decreases real wage growth (response variable) by -.0178 (approximately 1.8%). This finding is in line with theory (Phillips, 1978) and intuition. Higher lagged unemployment growth has negative impact on real wage growth, as employees have lower bargain power due to excess supply on the labour market.

More interestingly, coefficient of lagged underemployment index growth is -.0308 (approximately negative 3.1%). It means that growth in real wage is significantly more responsive to changes in underemployment index growth, than changes in unemployment rate growth. This result is in line with my expectations, as underemployment index includes more information about the slack on the labour market than unemployment rate. The coefficient of lagged underemployment index growth is almost twice as large as unemployment rate growth. This is promising indicator, as it shows that underemployment index might be more accurate predictor of wage movements.

(14) $\ln(W_t) = \alpha_2 + \beta_2 \Delta ln(U_t) + \delta_4 ln(U_{t-1}) + \lambda_2 t + \upsilon_t$

In equation (14), from Gregg and Fernandez-Salgado (2014) paper, beta coefficient allows for "short-run effects of changes in log unemployment to affect log real wages" (Gregg and Fernandez-Salgado, 2014).

I run regression (14) expressed in terms of residuals of real wage growth and unemployment rate/underemployment index growth accounting for changes in the intercept and linear trend (see equations (15) and (16)). I again supress constant term and report robust standard errors.

(15) $\varepsilon_{w,t} = \beta_{21}\varepsilon_{und,t} + \delta_{21}\varepsilon_{und,t-1} + \upsilon_{3t}$

(16) $\varepsilon_{w,t} = \beta_{22}\varepsilon_{u,t} + \delta_{22}\varepsilon_{u,t-1} + \upsilon_{4t}$

Both lagged underemployment index growth and lagged unemployment rate growth have negative impact on real wage growth (*Table 13*). Surprisingly, underemployment index growth in current period t has positive impact on real wage growth, while unemployment rate growth in current period has negative effect. It might be the case that employers do not have enough time to adjust wages to current labour market conditions, which are included in underemployment index, as those data are not published by the official statistical institute, as well as are not so easily accessed at the aggregate level. However, unemployment data are in line with Gregg and Fernandez-Salgado (2014) results. The current period changes are badly determined by model (15), which suggests that I "did not pick up effects of economic cycle on real wages other than by lagged measures of slack growth" (Gregg Fernandez-Salgado, 2014).

Table 13 Exploratory Time Series Regression (15) and (16)

Regression of Real Wage on Underemployment Index, or Unemployment Rate*	
Underemployment Index (t)	.0165 (.0279)
Underemployment Index (t-1)	-.0380 (.0282)
Unemployment Rate (t)	-.0286 (.0418)
Unemployment Rate (t-1)	-.0018 (.0393)

**Robust standard errors in parentheses.*

Above results suggest, that it is possible that both unemployment rate growth and underemployment index growth negatively impacts real wage growth. When I lag both indicators of slack of the labour market, they explain wage movements in line with macroeconomic theory and my expectations. However, results are ambiguous for current period changes. In order to explore relationship in more detail, I will run the Granger causality tests.

4.5 VAR Models

Before I run Granger causality tests, I need to construct VAR models. VAR analysis is a regression analysis involving stationary variables, where the past values of the variables are allowed to affect each other (Hamilton, 1994). I construct two bivariate VAR models with p and k lags.

I base specification of VAR model on Gregg and Fernandez-Salgado (2014) paper. I build two VAR models (17) and (18). Model (17) includes real wage growth and underemployment index growth. Model (18) includes real wage growth and unemployment rate growth. Models traces the dynamics interaction of slack on labour market and real wage (Hamilton, 1994).

$$(17)\quad \begin{pmatrix} \varepsilon_{w,t} \\ \varepsilon_{und,t} \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} + \begin{bmatrix} \delta_{111} & \delta_{112} \\ \delta_{121} & \delta_{122} \end{bmatrix} \begin{pmatrix} \varepsilon_{w,t-1} \\ \varepsilon_{und,t-1} \end{pmatrix} + .. + \begin{bmatrix} \delta_{p11} & \delta_{p12} \\ \delta_{p21} & \delta_{p22} \end{bmatrix} \begin{pmatrix} \varepsilon_{w,t-p} \\ \varepsilon_{und,t-p} \end{pmatrix} + \begin{pmatrix} \eta_{1t} \\ \eta_{2t} \end{pmatrix}$$

$$(18)\quad \begin{pmatrix} \varepsilon_{w,t} \\ \varepsilon_{u,t} \end{pmatrix} = \begin{pmatrix} \alpha_3 \\ \alpha_4 \end{pmatrix} + \begin{bmatrix} \phi_{111} & \phi_{112} \\ \phi_{121} & \phi_{122} \end{bmatrix} \begin{pmatrix} \varepsilon_{w,t-1} \\ \varepsilon_{u,t-1} \end{pmatrix} + .. + \begin{bmatrix} \phi_{k11} & \phi_{k12} \\ \phi_{k21} & \phi_{k22} \end{bmatrix} \begin{pmatrix} \varepsilon_{w,t-k} \\ \varepsilon_{u,t-k} \end{pmatrix} + \begin{pmatrix} \eta_{3t} \\ \eta_{4t} \end{pmatrix}$$

This VAR analysis is an atheoretical analysis of short-term relationship between underemployment index/unemployment rate and real wages (Hamilton, 1994). I do not use labour market theory to explicitly specify the structural relationship between variables. Instead, I just decide which variables I want to include in VAR model. I base analysis on assumption, that indicators of slack on the labour market and real wages move together over time and there is some autocorrelation between those macroeconomic variables (Hamilton, 1994).

VAR approach to model the relationship between time series variables has several drawbacks. It is sensitive to lag-selection – I discuss approach towards this below. VAR results also do not allow to differentiate between correlation and causality. In order to overcome this problem, I run Granger Causality Tests. VAR can be also highly dimensional, if researchers try to model relationship between many variables (Hamilton, 1994). It is not the case in this dissertation, as I include two variables in each VAR model.

The first step in building VAR model is selecting the optimal lag length according to selection-order criteria. Monte Carlo experiments suggests that it is better to error on the side of including too many lags. However, if number of lags is too large, then the power of a test will suffer (Hamilton, 1994). I choose number of lags based on pre-estimation VAR selection statistics. Firstly, I set maximum lag to according to the formula suggested by Schwert (1989) $lag_{\max} = \left[12\times\left(\frac{T}{100}\right)^{0.25}\right]$ which again states maximum number of lags to be 11, as I analyse $T = 71$ data points in each case. I keep default confidence interval of 0.95. In the beginning, I test the most parsimonious VAR model. Selection of lags is made according to four tests (final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC)). Selection is done under the null hypothesis is that all the coefficients on the p-th/k-th lags of the endogenous variables are zero.

Below, I briefly explain how I choose VAR models (17) and (18) - testing for stability and autocorrelation.

4.5.1 VAR Model of Real Wage and Underemployment Index

I want to choose lag order of model (17). I start with the most parsimonious model of lag 1 (selected by SBIC and HQIC). I set up VAR model, and test for stability and for serial correlation.

Although model passes test for stability (all eigenvalues lie inside the unit circle – Graph 12), I need to reject the null hypothesis that there is no autocorrelation (*Table 14*). Evidence of autocorrelation means, that model requires re-estimation.

Graph 12 Stability of VAR(1) Model (17)

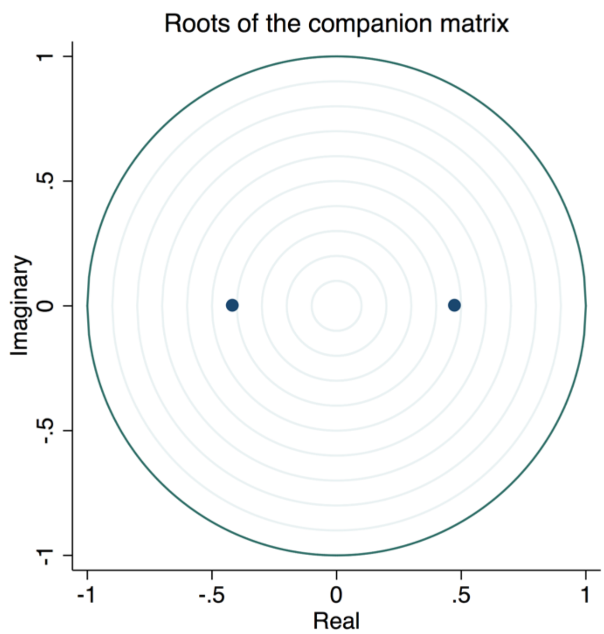


Table 14 Testing for Serial Correlation of VAR (1) Model (17)

Lag	Chi2	Df	Prob>Chi2
1	10.0790	4	0.03912
2	8.3559	4	0.07938

I re-estimate model with 2 lags (selected by AIC and FPE). I set up VAR model and test for stability and serial autocorrelation. Model pass test for stability (Graph 13) and there is no evidence of autocorrelation (*Table 15*) – P-values are greater than 0.05, thus I do not reject the null hypothesis of no autocorrelation at lag order. Vector autoregression model (17) with two lags is chosen.

Graph 13 Stability of VAR(2) Model (17)

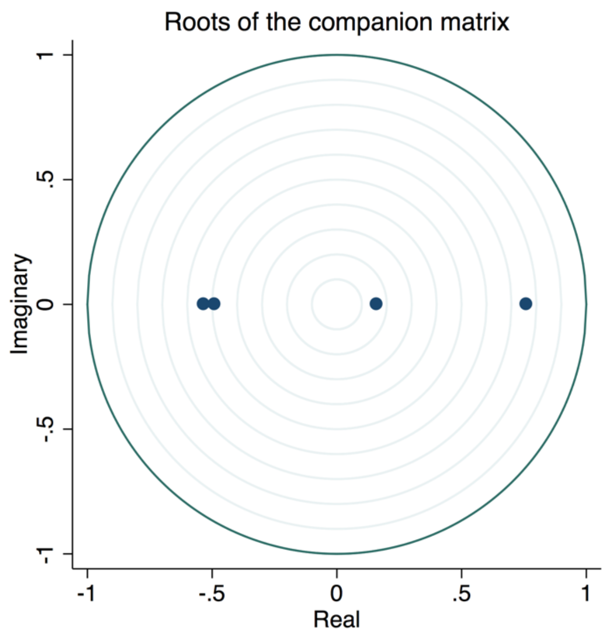


Table 15 Testing for Serial Correlation of VAR (2) Model (17)

Lag	Chi2	Df	Prob>Chi2
1	1.2131	4	0.87593
2	4.4668	4	0.34650

4.5.2 VAR Model of Real Wage and Unemployment Rate

Now, I am choosing lag order of model (18). I start with the most parsimonious model of lag 1 (selected by FPE, AIC, HQIC, SBIC). I set up VAR model and test for stability and for serial correlation. Model passes test for stability, as all eigenvalues lie inside the unit circle (Graph 14). I do not reject the null hypothesis that there is no autocorrelation, as p-values of autocorrelation tests are greater than 0.05 at each lag (*Table 16*). Vector autoregression model (18) with one lag is chosen.

Graph 14 Stability of VAR(1) Model

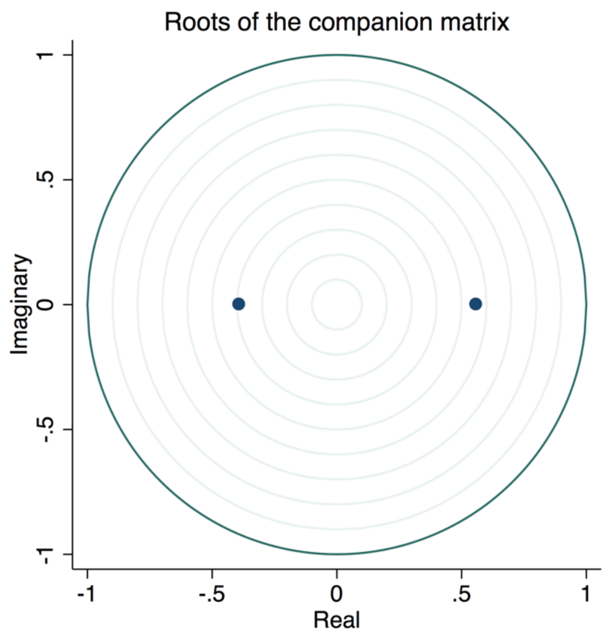


Table 16 Testing for Serial Correlation of VAR (1)

Lag	Chi2	Df	Prob>Chi2
1	5.1842	4	0.26892
2	5.4865	4	0.24092

4.6 Granger Causality Tests

Granger causality test is a way to investigate if one variable Granger-cause another variable. Given two stationary variables x, y and correct VAR model, this test reveals if variable x helps to predict variable y, or if variable y helps to predict variable x, or both (Patterson, 2000). So far, I ran exploratory regressions, which attempts to establish type of relationship between the topic variables. Granger causality test allows establishing both if there is any relationship between variables and direction of this relationship. Granger causality test run under the null hypothesis that e.g. variable x does not granger-cause variable y. If null hypothesis is rejected, then I conclude that causality of x to y exist. This method is a "probabilistic account of causality and it finds patterns in correlation" (Patterson, 2000). I define null hypothesis of Granger causality tests based on VAR models: (17) with p = 2 lags and (18) with k = 1 lag.

Null hypothesis for VAR (2) model (17):

(19) H_0: $\delta_{112} = \delta_{212} = 0$

(20) H_0: $\delta_{121} = \delta_{221} = 0$

Null hypothesis for VAR (1) model (18):

(21) H_0: $\phi_{112} = 0$

(22) H_0: $\phi_{121} = 0$

Table 17 Granger Causality Test, VAR(2) Underemployment Growth – Real Wage Growth

Equation	Excluded	Chi2	df	Prob>Chi2
Real Wage*	Underemployment Index*	1.1064	2	.575
Underemployment Index*	Real Wage*	3.2856	2	.193

*growth

Results of the Granger causality test based on VAR(2) model (17) show, that I cannot reject the null hypothesis that underemployment index growth does not Granger-cause real wage growth (*Table 17*). Similarly, I cannot reject the null hypothesis that real wage growth does not Granger-cause underemployment index growth. It might be worth to note, that p value of Granger-causation from real wage growth to underemployment index growth is more significant than the opposite direction, but the significance in not at any reasonable level.

Table 18 Granger Causality Test, VAR(1) Unemployment-Wages

Equation	Excluded	Chi2	df	Prob>Chi2
Real Wage*	Unemployment Rate*	.6298	1	0.427
Unemployment Rate*	Real Wage*	.7123	1	0.427

*growth

Next, I run Granger causality test on VAR(1) model (18). Result (*Table 18*) show that I cannot reject the null hypothesis, that real wage growth does not Granger-cause unemployment rate growth. I also cannot reject the null hypothesis that unemployment rate growth does not Granger-cause real wage growth.

Although the results of exploratory time series regression discussed in subsection 4.4 are promising, Granger causality tests do not indicate any relationship between underemployment index growth and real wage growth. Tests also do not detect any relationship between unemployment rate growth and real wage growth. Latter findings are in line with results of Gali (2011), who also performed Granger causality tests between quarterly unemployment rate growth and real wage growth (1964 q1 – 2009 q1, US data), but did not find any significant causation.

Some of previous researchers find that movements in unemployment rate affect real wage in selected periods (see section 2.1 and *Table 1*). I cannot clearly state that there is a relationship between real wage growth and underemployment index growth between 2000 q2 – 2017 q4, as I do not have enough evidence to support this statement. Exploratory regression results obtained in subsection 4.4 are not sufficient, as Gregg and Fernandez-Salgado use them just as a possible indicator of the relationship. Researchers are not trying to obtain model, which fully explains how real wage movements are determined. They just want indication of direction in which real wage moves, given change in unemployment rate. I am also certain that models proposed by Gregg and Fernandez-Salgado (2014) suffer from omitted variable bias, as there are many various factors affecting real wage growth. I try to override this problem by establishing Granger causation. Establishing Granger causation could be the sufficient evidence. Although VAR models may still suffer from omitted variable bias, Granger causation could simply indicate if e.g. underemployment index growth changes help to predict real wage growth changes. Then, I would be able to establish the relationship between topic variables at least in a statistical sense. As shown above, it is not the case within the period I analyse.

Chapter 5: Summary

The main objective of this dissertation has been to discuss the concept underemployment index and test the short-term relationship between underemployment index growth and real wage growth. I have built on existing literature by updating Bell and Blanchflower underemployment index and including analysis of sum of underemployed/overemployed hours. I have also added value by analysing short-term relationship of the topic variables, which was not analysed by any previous researcher.

Firstly, I have found that the difference between underemployment index and unemployment rate is very small since 2017. It is the case, because the quantity of underemployed hours is recently close to the quantity of overemployed hours. Total number of underemployed and overemployed hours has remained on the post-downturn level. It is a good example of why underemployment index is not an ideal measure of a labour market slack.

My first recommendation for future research is to focus on construction improvement of underemployment index, by capturing the miss-match of hours on a labour market. It could be in a form of penalty term within underemployment index (e.g. the higher miss-match, the higher underemployment index, even if over/under employed hours cancel each other out – by assumption these hours cannot be traded freely). Another possible solution is to focus solely on unutilised potential of labour force by excluding overemployed hours from underemployment index. If any of these solutions were implemented, I would expect underemployment index to have much higher value than the one I computed. That would of course change established relationships and would require additional analysis.

Another finding is that I cannot clearly state, that there is a significant relationship between underemployment index growth and real wage growth. I also cannot conclude that underemployment index growth explains wage growth movements more accurately than unemployment rate growth. I have expected underemployment index growth to be better predictor of real wage growth movements due to speculation of researchers and macroeconomic theory. On one hand, exploratory time series regression has shown that real wage growth is more sensitive to changes in lagged underemployment index growth, than to changes in lagged unemployment rate growth. On the other hand, Granger causality tests have not shown short-term causation in any direction between real wage growth and underemployment index growth, or unemployment rate growth.

My second recommendation for future research is to focus on cointegration analysis of long-term underemployment index - real wage relationship. In my analysis, I have found all variables to be integrated of order one. Consequently, I have lost information about long-term level of underemployment index/unemployment rate and real wage. That is why it can be benefitial to perform cointegration analysis of the real wage and unemployment rate/underemployment index relationship. Furthermore, I have analysed data within short period - 17 years of data. It is also possible, that there exist significant relationship in longer period. I would recommend replicating Granger causality tests in the future, once more years of data is available.

Bibliography

[1] Barnett A., Batten S., Chiu A, Franklin J. and Barriel M. (2014). 'The UK productivity puzzle', the Bank of England, Quarterly Bulletin pp. 114-127.

[2] Bell D. and G. Blanchflower D. (2014). 'Commentary: Labour Market Slack in the UK', National Institute Economic Review, No. 229 (August), pp. 4-11.

[3] Bell D. and G. Blanchflower D. (2013). 'How to Measure Underemployment', Peterson Institute for International Economics, WP 13-7.

[4] Bell D. and G. Blanchflower D. (2013). 'Underemployment in the UK Revisited', National Institute Economic Review, No. 224 (May), pp. 8-22.

[5] Bell D. and G. Blanchflower D. (2011). 'Underemployment in the UK in the Great Recession', National Institute Economic Review, No. 215 (January), pp. 23-33.

[6] Bell D. and G. Blanchflower D. (2010). 'UK Unemployment in the Great Recession', National Institute Economic Review, No. 214 (October), pp. 3-25.

[7] Feldman D. (1996). 'The Nature, Antecedents and Consequences of Underemployment', Journal of Management, Vol. 22, Issue 3 (June).

[8] Gali J. (2011). 'The return of the wage Phillips curve', Journal of the European Economic Association, vol. 9(3), pp.436-61.

[9] Gregg P., Machin S. and Fernandez-Salgado M. (2014). 'Real Wages and Unemployment in the Big Squeeze', The Economic Journal, No. 124 (May), pp. 408-432.

[10] Hamilton, J. (1994). Time series analysis. Princeton, N.J.: Princeton University Press, pp.291-351.

[11] Hines J., Hoynes H. and Krueger A. (2001). 'Another look at whether a rising tide lifts all boats', The Roaring Nineties: Can Full Employment be Sustained? New York: Russell Sage Foundation.

[12] Layard R., Nickell S., and Jackman R. (1991). 'Unemployment', Oxford: Oxford University Press.

[13] Lopez L. and Weber S. (2017). 'Testing for Granger causality in panel data', Institute of Economic Research, working paper 17-03, pp.2-12.

[14] Mosconi, Rocco & Paruolo, Paolo, 2017. "Identification conditions in simultaneous systems of cointegrating equations with integrated variables of higher order," Journal of Econometrics, Elsevier, vol. 198(2), pages 271-276.

[15] Mc-Kee Ryan and Harvey J. (2011). ' "I Have a Job But . . . " A Review of Underemployment', Journal of Management, Vol. 37 No. 4, pp. 962- 996.

[16] Ons.gov.uk. (2018). EMP16: Underemployment and overemployment - Office for National Statistics. [online] Available at: https://www.ons.gov.uk/ employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/underemploymentandoveremploymentemp16 [Accessed 28 Apr. 2018].

[17] Office for National Statistics. Social Survey Division, Northern Ireland Statistics and Research Agency. Central Survey Unit, 2017, Quarterly Labour Force Survey, 1992-2017: Secure Access, [data collection], UK Data Service, 11th Edition, Accessed 25 January 2018. SN: 6727, http://doi.org/10.5255/UKDA-SN-6727-12.

[18] Ons.gov.uk. (2017). EMP16: Underemployment and overemployment - Office for National Statistics. [online] Available at: https://www.ons.gov.uk/ employmentandlabourmarket/ peopleinwork/employmentandemployeetypes/ datasets/ underemploymentandoveremployment emp16 [Accessed 9 Dec. 2017].

[19] Ons.gov.uk. (2018). Labour Force Survey – user guidance - Office for National Statistics. [online] Available at: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/methodologies/labourforcesurveyuserguidance [Accessed 28 Apr. 2018].

[20] Patterson K. (2000). 'An Introduction to Applied Econometrics – a time series approach', Chapter 6, pp.208-216.

[21] Phillips A. (1958). 'The relation between unemployment and the rate of change of money wages in the United Kingdom, 1861-1957', Economica vol. 25(100), pp. 283-99.

[22] Salman K. (2012). 'Testing for Causal Nexus between Output and Unemployment: Swedish Data', International Business Research, Vol. 5, No. 10, pp.29-45.

[23] Sargan D. (1964). 'Wages and prices in the United Kingdom: a study in the econometric methodology', Econometrics and Quantitative Economics, pp.257-314.

[24] Savic M. (2017). 'Labour market economic commentary: November 2017', Labour Market Economic Commentary.

[25] Sapsford D. and Tzannatos Z.. 'The Economics of the Labour Market', Chapter 7, pp.155-172.

[26] Walling A. and Clancy G. (2010). 'Underemployment in the UK labour market', Economic & Labour Market Review Vol. 4 No. 2 pp. 16-24.

Appendices

Table 19 Nominal Wage, CPI Deflator, ONS Unemployment Rate. Source: ONS

Year	Quarter	Nominal Wage	CPI (2015=100)	ONS Unemployment Rate
2000	q2	311.0	86.6	5.5
	q3	315.5	85.9	5.3
	q4	321.1	86.3	5.2
2001	q1	325.1	85.1	5.1
	q2	328.1	86.2	5.0
	q3	330.6	85.3	5.1
	q4	334.2	85.3	5.2
2002	q1	335.2	84.7	5.2
	q2	340.2	84.8	5.2
	q3	341.7	84.0	5.3
	q4	343.1	84.3	5.1
2003	q1	345.4	83.9	5.2
	q2	349.3	84.1	4.9
	q3	352.4	83.7	5.0
	q4	356.5	84.2	4.9
2004	q1	358.3	83.6	4.8
	q2	364.2	84.0	4.8
	q3	368.7	83.2	4.7
	q4	373.5	83.9	4.7
2005	q1	375.7	83.5	4.7
	q2	380.4	84.0	4.8
	q3	386.4	83.7	4.7
	q4	389.6	84.3	5.1
2006	q1	395.8	83.8	5.2
	q2	398.7	85.0	5.5
	q3	401.6	85.3	5.5
	q4	407.6	85.9	5.5
2007	q1	420.6	85.7	5.5

	q2	415.9	86.5	5.4
	q3	421.9	85.6	5.3
	q4	423.5	86.8	5.2
2008	q1	439.8	87.1	5.2
	q2	432.7	89.1	5.4
	q3	434.2	90.0	5.9
	q4	435.0	89.7	6.4
2009	q1	428.5	88.9	7.1
	q2	436.8	90.0	7.8
	q3	436.6	90.4	7.8
	q4	438.2	91.4	7.8
2010	q1	440.7	91.9	8.0
	q2	443.8	93.0	7.9
	q3	445.1	92.6	7.8
	q4	447.8	94.1	7.9
2011	q1	453.0	95.6	7.8
	q2	454.3	97.0	7.9
	q3	454.7	97.3	8.3
	q4	456.5	98.8	8.4
2012	q1	456.3	99.0	8.2
	q2	461.1	99.3	8.0
	q3	462.8	98.9	7.9
	q4	462.1	100.4	7.8
2013	q1	459.0	100.9	7.8
	q2	470.9	101.3	7.7
	q3	466.0	101.2	7.6
	q4	466.7	102.1	7.2
2014	q1	467.3	102.1	6.8
	q2	469.6	102.4	6.3
	q3	470.3	101.7	6.0
	q4	476.8	101.8	5.7
2015	q1	478.7	100.2	5.5
	q2	482.2	100.4	5.6

	q3	484.7	99.6	5.3
	q4	486.4	99.7	5.1
2016	q1	489.1	98.7	5.1
	q2	494.1	98.8	4.9
	q3	496.5	98.5	4.8
	q4	498.8	99.9	4.8
2017	q1	500.3	100.4	4.6
	q2	504.4	101.4	4.4
	q3	507.9	101.5	4.3
	q4	510.5	103.2	4.4

Table 20 Augmented Dickey-Fuller Test of Real Wage (3 lags specified)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-2.309	-3.556	-2.916	-2.593	0.1692

Table 21 Augmented Dickey-Fuller Test of First Difference Log Real Wage (4 lags specified)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-1.857	-3.559	-2.918	-2.594	0.3527

Table 22 Augmented Dickey-Fuller Test of Second Difference Log Real Wage (3 lags specified)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-7.502	-3.559	-2.918	-2.594	0.0000

Table 23 Augmented Dickey-Fuller Test of Unemployment Rate (2 lags specified)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-1.714	-3.555	-2.916	-2.593	0.4240

Table 24 Augmented Dickey-Fuller Test of First Difference Log Unemployment Rate (1 lag specified)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-2.880	-3.555	-2.916	-2.593	0.0477

Table 25 Augmented Dickey-Fuller Test of Underemployment Index (3 lags specified)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-1.617	-3.556	-2.916	-2.593	0.4745

Table 26 Augmented Dickey-Fuller Test of First Difference of Log Underemployment Index (2 lags specified)

Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability
-3.006	-3.556	-2.916	-2.593	0.0344

Table 27 Residuals Obtained from Regression (8), (9) and (10)

Year	Quarter	$\varepsilon_{w,t}$	$\varepsilon_{u,t}$	$\varepsilon_{und,t}$
2000		-	-	-
	q3	0.0130472	-0.0327418	-0.0660993
	q4	0.0033694	-0.0162002	-0.0698315
2001	q1	0.0171113	-0.0259275	-0.0358569
	q2	-0.0130796	-0.0106597	-0.0617515
	q3	0.0086942	0.0123028	0.0109149
	q4	0.0013829	0.0189774	0.025088
2002	q1	0.000432	-0.0020385	-0.0247997
	q2	0.0044022	-0.0006859	0.0164054
	q3	0.004385	0.0287699	0.0478333
	q4	-0.00879	-0.0357496	-0.0832019
2003	q1	0.0018039	0.0107753	0.0264972
	q2	-0.000412	-0.0441948	-0.0427888
	q3	0.0040803	0.022374	0.0015261
	q4	-0.0039024	-0.029503	-0.0540347
2004	q1	0.0027519	-0.0191045	0.0079939
	q2	0.0022836	0.002421	-0.0348979
	q3	0.0122667	-0.0247624	0.0314197
	q4	-0.0048017	0.0106278	-0.000436
2005	q1	0.001348	-0.0075022	0.0054816
	q2	-0.0030775	0.0139613	0.0799918
	q3	0.0097294	-0.0033854	-0.0364822
	q4	-0.0082545	0.0851184	0.1097182
2006	q1	0.0122094	0.0171623	0.0477783
	q2	-0.0162182	0.0458392	0.0662989
	q3	-0.0057506	0.0025884	-0.0124389
	q4	-0.001492	0.0046911	0.0431175
2007	q1	0.0243244	0.0031917	0.0014959
	q2	-0.0300016	-0.028996	-0.0471648
	q3	0.0152808	-0.0068504	0.0085742
	q4	-0.0195346	-0.0286928	-0.0515782

2008	q1	0.0248251	0.0053189	0.0363064
	q2	-0.0484132	0.0328751	0.0549209
	q3	-0.0028838	0.0957574	0.1498155
	q4	0.0085233	0.0868466	0.1100017
2009	q1	-0.0028991	0.1126839	0.1549214
	q2	0.0100492	0.0983819	0.105219
	q3	-0.0022152	0.0159232	0.0192558
	q4	-0.0047875	-0.0036066	-0.0194772
2010	q1	0.0026075	0.0355694	0.0340165
	q2	-0.0029364	-0.0146099	-0.0277964
	q3	0.0091779	-0.0075937	0.0411011
	q4	-0.0082994	0.0196258	0.0125207
2011	q1	-0.0029414	-0.0052963	-0.0042571
	q2	-0.0104832	0.0256249	0.0282856
	q3	-0.001219	0.0539295	0.0556809
	q4	-0.0106816	0.0101558	0.0029708
2012	q1	-0.0017926	-0.0166298	-0.0044404
	q2	0.0076138	-0.0190831	-0.0137962
	q3	0.0078672	-0.013393	-0.024598
	q4	-0.0167783	-0.0003641	0.007511
2013	q1	-0.0119315	0.0095112	0.0206543
	q2	0.0210106	-0.0071767	-0.0150684
	q3	-0.0104056	-0.0123733	-0.021603
	q4	-0.0082882	-0.0473507	-0.0578691
2014	q1	-0.0001021	-0.0612738	-0.0680874
	q2	0.0005357	-0.0664279	-0.0716816
	q3	0.0066276	-0.0470919	-0.0429344
	q4	0.0106767	-0.0397994	-0.0784275
2015	q1	0.0177637	-0.0228093	0.0079366
	q2	0.0028818	0.0159285	-0.0191692
	q3	0.0105978	-0.0513124	-0.0705933
	q4	-0.0004803	-0.0338596	-0.0303162
2016	q1	0.0125834	0.004735	-0.0265846

	q2	0.0059909	-0.0299398	-0.0291679
	q3	0.0042736	-0.0159099	0.0198509
	q4	-0.0132232	-0.0031885	-0.0378945
2017	q1	-0.0059159	-0.0305579	-0.0414775
	q2	-0.0059586	-0.0344114	-0.0894216
	q3	0.001508	-0.0330505	-0.0135077
	q4	-0.0160656	0.0324364	0.0384273

Table 28 Vector Autoregression (two lags) of Real Wage Growth (W) and Underemployment Index Growth (UND)

	Coefficient	Standard Error	P-Value
W			
W Lag 1	-.3571998	.122072	0.003
W Lag 2	.1043048	.123536	0.398
UND Lag 1	-.017356	.0289796	0.549
UND Lag 2	-.0140624	.0281115	0.617
Constant	-.000246	.0013135	0.851
UND			
W Lag 1	-.8663309	.4779548	0.070
W Lag 2	-.3241113	.4836869	0.503
UND Lag 1	.2518126	.1134655	0.026
UND Lag 2	.3490395	.1100665	0.002
Constant	.0021323	.0051426	0.678

Table 29 Vector Autoregression (one lag) of Real Wage Growth (W) and Unemployment Rate (U)

	Coefficient	Standard Error	P-Value
W			
W Lag 1	-.385118	.1120182	0.001
U Lag 1	-.0288095	.0363034	0.427
Constant	-.000113	.0013156	0.932
U			
W Lag 1	-.2599086	.3079563	0.399
U Lag 1	.5500497	.099804	0.000
Constant	.0007936	.0036167	0.826